Changes in the flesh of cooked farmed salmon (*Oncorhynchus kisutch*) with previous storage in slurry ice (-1.5ºC)

Alicia Rodríguez [a], Nicolás Carriles [a], José M. Cruz [b], and Santiago P. Aubourg [c,*]

[a] Department of Food Science and Chemical Technology, Faculty of Chemical and Pharmaceutical Science, University of Chile, Santiago (Chile)

[b] Department of Analytical Chemistry, Nutrition and Bromatology, University of Santiago de Compostela (Spain)

[c] Department of Food Technology, Instituto de Investigaciones Marinas (CSIC), Vigo (Spain)

* Correspondent: FAX: +34986292762; e-mail: saubourg@iim.csic.es

ABSTRACT

Whole, farmed Coho salmon (*Oncorhynchus kisutch*) were sacrificed in slurry ice (-1.5ºC) then stored in this medium for further processing after 0, 5 and 9 days. They were cooked whole and the flesh was evaluated by sensory, physical and chemical techniques to establish if significant changes had occurred as a result of the storage period. Initial samples from harvest were also evaluated for comparison. There was evidence of increases in trimethylamine, lipid hydrolysis, lipid oxidation (anisidine and thiobarbituric acid values) and interaction compound formation (fluorescence and browning measurements). The fish structure became more breakable with longer storage but there were no changes in sensory assessments for rancid and putrid odours, so that scores were less than 0.5 on a 11 point scale. From the present results, primary and secondary lipid oxidation development and further interaction compound formation appears to be the main measurable indicators of quality changes in cooked Coho salmon. However, and according to sensory appreciation, slurry ice has shown to be a suitable medium for previous storage of Coho salmon for periods of up to 9 days.

Key Words: *Oncorhynchus kisutch*, farming, chilling, cooking, deterioration, quality

Running Title: Quality deterioration in cooked farmed salmon

INTRODUCTION

Cooking destroys pathogenic and spoilage microorganisms, inactivates enzymes and enhances desirable flavours and tastes of fish flesh (McLay, 1982). However, owing to the thermal sensitivity of a broad number of fish constituents and nutrients several detrimental effects due to cooking have been reported: i.e., heat degradation of nutrients, oxidation of vitamins and lipids, leaching of water-soluble vitamins, minerals and proteins, and toughening and drying of sensitive protein tissues (Aitken & Connell, 1979; Pigott & Tucker, 1990).

Most of the quality problems found in cooked fish products are directly related to the initial quality of the fresh raw material, which declines continuously post-mortem during its preliminary refrigerated storage (Olafsdóttir et al., 1997). Accordingly, quality of processed fish will depend to a large extent on the adequacy of the preliminary holding methods used (Slabyj & True, 1978; Aubourg & Medina, 1997). In this sense, great efforts have been carried out in the search of appropriate chilling conditions so that autolytic degradation and microbial spoilage would be slowed and minimised (Whittle, Hardy, & Hobbs, 1990; Ashie, Smith, & Simpson, 1996).

In recent years the fishing sector has suffered from dwindling stocks of traditional species as a result of dramatic changes in their availability. This has prompted fish technologists and the fish trade to pay more attention to aquaculture techniques as a source of fish and other seafood products (Stickney, 1990). Among cultivated fish, Coho salmon (*Oncorhynchus kisutch*), also called silver salmon, has received great attention because of its increasing production in countries like Chile, Japan and Canada (FAO, 2006a) in parallel to important capture production in countries such as USA, Russian Federation, Canada and Japan (FAO, 2006b). Most research on

this fish species has been carried out on genetic aspects and farming conditions during aquaculture production (Estay, Díaz, Neira, & García, 1997; Winkler, Bartley, & Díaz, 1999). However, previous research concerning quality changes produced during processing has been scarce, only accounting for freezing (Braddock & Dugan, 1972; Rodríguez, Losada, Larraín, Quitral, Vinagre, & Aubourg, 2007) and chilling (Barnett, Nelson, & Poysky, 1991; Aubourg, Quitral, Larraín, Rodríguez, Gómez, Maier, & Vinagre, 2007) conditions.

The present study focuses on the employment of farmed fish species as raw material for the commercialisation of thermally-treated fish products. In it, Coho salmon was chosen, so that the effect of a short preliminary chilled storage on quality degradation in the resulting cooked product was studied through sensory, physical and chemical changes. Because temperature control is so important, an advanced biphasic chilling system in which slurry ice holds the fish at a lower temperature than traditional flake ice was employed as slaughtering and holding process (Yamada, Fukusako, & Kawanami, 2002).

MATERIALS AND METHODS

Chilling system (slurry ice) elaboration

A slurry ice prototype (FLO–ICE, Kinarca S.A.U., Vigo, Spain) was used. The composition of the slurry ice binary mixture was 40 % ice/60 % water, prepared from filtered seawater (salinity: 3.3 %). The temperature of the slurry ice mixture was –1.5 ºC and the calculated salt content about 2.0%. The average temperature of the specimens was in the range of –1.0ºC to –1.5ºC.

Raw fish, chilling storage, sampling, cooking and chemicals

Specimens of farmed Coho salmon (*Oncorhynchus kisutch)* (weight range: 2.8-3.2 kg) were obtained from *Comercial Xanquéi* (Lousame, La Coruña, Spain) in May 2006. Individual fish gonads were at the $4^{th}/5^{th}$ stage of Maier's scale of gonad maturity. The fish were sacrificed at the cultivation plant by immersion in slurry ice. Individuals were kept under this chilling condition during transportation to the laboratory. Upon arrival in the laboratory, the fish specimens were neither headed nor gutted, but directly placed in an isothermal room at 2ºC and were surrounded by slurry ice at a 1:1 fish to ice ratio. The slurry ice mixture was renewed each three days of storage. During the chilled storage, once in a day a temperature logger was employed at different parts of the fish to monitor its temperature.

Twenty-four hours after slaughtering, four individuals were not thermally-treated and were studied as initial raw fish (day 0). The remaining fish (12 individuals) were taken for the cooking process on days 0, 5, and 9 of chilled storage. Whole and ungutted salmon specimens were steam cooked during 25 minutes in our pilot plant (102-103ºC) to a final backbone temperature of 65ºC; the fish were then cooled at room temperature (15-18ºC) for about 2 hours. For each individual fish, the white muscle was then collected and splitted into three different parts. Two of them were directly employed for the sensory and physical analyses, respectively; the third one was homogenised and used for the chemical analyses. Both in raw and in cooked samples, each individual fish was studied separately from others to achieve the statistical study (n=4).

Chemicals employed along the present work (solvents, reagents) were reagent grade (E. Merck; Darmstadt, Germany).

Composition analyses

Water content was determined by weight difference between the homogenised fish muscle (1-2 g) before and after 24 h at 105 ºC. Results are expressed as g water / 100 g muscle.

The lipid fraction was extracted from the fish muscle by the Bligh and Dyer (1959) method. Quantification results are expressed as g lipid / 100 g muscle.

NaCl contents were determined after boiling portions of fish muscle in the presence of HNO_3, followed by the addition of excess 0.1N $AgNO_3$ and the titration of non-neutralised silver nitrate with 0.1N NH_4SCN (AOAC, 1990). The results are expressed as g NaCl / 100 g muscle.

Volatile amine formation and pH assessment

Total volatile base-nitrogen (TVB-N) values were measured by the Antonacopoulos (1960) method, with some modifications. Briefly, fish muscle (10 g) was extracted with 6% (w/v) perchloric acid and brought up to 50 ml, determining the TVB-N content –after steam-distillation of the acid extracts rendered alkaline to pH 13 with 2% (w/v) NaOH – by titration of the distillate with 10 mM HCl. The results are expressed as mg TVB-N / 100 g muscle.

Trimethylamine-nitrogen (TMA-N) values were determined by means of the picrate method, as previously described (Tozawa, Erokibara, & Amano, 1971). This involves the preparation of a 5% (w/v) trichloroacetic acid extract of fish muscle. The results are expressed as mg TMA-N / 100 g muscle.

The evolution of pH values in Coho salmon muscle was determined by means of a 6-mm diameter insertion electrode (Crison, Barcelona, Spain).

Lipid damage analysis

Free fatty acid (FFA) content was determined by the Lowry and Tinsley (1976) method based on complex formation with cupric acetate-pyridine followed by spectrophotometric (715 nm) assessment. Results are expressed as g FFA / 100 g lipids.

Primary lipid oxidation was determined by means of the peroxide value (PV) according to the ferric thiocyanate method (Chapman and McKay, 1949). The results are expressed as meq active oxygen / kg lipids.

The anisidine value (AV) was determined in fish muscle according to the AOCS (1993) method, based on the reaction between α- and β-unsaturated aldehydes (primarily 2-alkenals) and p-anisidine reagent. AV is expressed as 100 times the absorbance measured at 350 nm in a 1 cm path length cuvette from a solution containing 1 g lipid / 100 ml reaction medium.

The thiobarbituric acid index (TBA-i) was determined according to Vyncke (1970). This method is based on the reaction between a trichloracetic extract of the fish muscle, and thiobarbituric acid at high temperature (95-97ºC), the resulting chromophore being measured at 532 nm. Results are expressed as mg malondialdehyde / kg fish muscle.

Interaction compound formation

Formation of fluorescent compounds was determined with a Perkin Elmer LS 3B fluorimeter by measurements at 393/463 nm and 327/415 nm as previously described (Aubourg & Medina, 1997). The relative fluorescence (RF) was calculated as follows: $RF = F/F_{st}$, where F is the fluorescence measured at each excitation / emission maximum, and F_{st} is the fluorescence intensity of a quinine sulphate solution (1 µg / ml in 0.05 M H_2SO_4) at the corresponding wavelength. The fluorescence ratio (FR) was

calculated as the ratio between the two RF values: FR = $RF_{393/463}$ nm / $RF_{327/415}$ nm. The FR value was determined in the aqueous phase resulting from the lipid extraction of the fish muscle.

Browning development was determined spectrophotometrically at 420 nm in the lipid extract of the edible flesh. The results were calculated using the equation: Browning = A x V / w, where A is the absorbance reading at 420 nm, V is the volume (ml) of the sample and w is the amount (mg) of the lipid sample.

Textural analysis

A shear test was used to evaluate texture. Firmness and cohesivity were determined from a stress-distance curve obtained from a Universal Testing Machine (Lloyd Instruments Limited, LR-5K, Hampshire, United Kingdom) including a load cell of 500 N (Jonsson, Sigurgisladóttir, Hafsteinsson, & Kristbergsson, 2000). The shear force or firmness was measured as the maximum peak force (N) required to shear/cut through the samples; cohesivity was measured during the upward movement of the blade and was calculated as the deformation (mm) at maximum peak force (Sigurgisladóttir, Hafsteinsson, Jonsson, Nortvedt, Thomasses, & Torrisen, 1999).

Sensory analysis

The analysis of rancid and putrid odour development was conducted by a sensory panel consisting of ten experienced judges, according to Howgate (1992). Panellists had been involved in sensory analysis of different kinds of fish foods during the last ten years. Previously to the present experiment, a special training was carried out concerning raw and cooked salmon of different quality conditions.

At each sampling time, the fish muscle portions were presented to panellists in individual trays and were scored individually. The panel members shared samples tested. Rancid and putrid odour developments were evaluated using a Quantitative Descriptive Analysis (QDA) on a non-structured linear scale with numerical scores from 0 (stage of no rancidity/ putridity at all) to 10 (stage where no increase in rancidity/ putridity is possible); score 5.0 was considered the borderline of fish acceptability. Scores among panellists were averaged.

Statistical analyses

Data from the different measurements were subjected to one-way analysis of variance; comparison of means was performed using a least-square difference (LSD) method (Statsoft, 1994). A confidence interval at the 95% level ($p<0.05$) was considered in all cases.

RESULTS AND DISCUSSION

Composition analyses

The water and lipid contents of cooked salmon were included in the ranges 68.20-73.70 and 1.80-3.10 g / 100 g wet muscle, respectively (Table 1). Values for both constituents did not result in significant differences as a result of the preliminary icing time; differences in mean values may be attributed to fish-to-fish variation. Lipid content of the white muscle showed to be relatively low; as an explanation, it can be argued that fish individuals employed in the present experiment correspond to the year

time of lower lipid content (Hardy & Keay, 1972; Roth, Johansen, Suontama, Kiessling, Leknes, Guldberg, & Handeland, 2005).

Compared to the raw fish initial value, all kinds of cooked samples showed lower water contents, according to previous research on mackerel (Hearn, Sgoutas, Sgoutas, & Hearn, 1987) and albacore (García-Arias, Sánchez-Muniz, Castrillón, & Navarro, 1994; Castrillón, Álvarez-Pontes, García, & Navarro, 1996). Water loss can be explained in terms of denaturation of sarcoplasmic and myofibrillar proteins and disruption of the muscle structure, this leading to a decreasing water holding capacity of the protein fraction (Seet & Brown, 1983; Castrillón et al., 1996). For muscle lipid content, a cooking effect was not noticeable in the present experiment, although previous research concerning fattier fish species showed a lipid content increase in muscle as a result of cooking (Gallardo, Aubourg, & Pérez-Martín, 1989; García-Arias et al., 1994).

Comparison between the NaCl content in fish muscle before and after the cooking treatment did not result in a significant difference. Concerning the effect of the previous holding time, individual salmons that had been chilled the longest time (9 days) showed an important increase in NaCl when compared to their corresponding cooked samples previously chilled during 0 and 5 days. Slurry ice contains about 2% salt and the present results agree with previous research that slow absorption of NaCl occurs into the fish during the storage period (Losada, Piñeiro, Barros-Velázquez, & Aubourg, 2005). Despite that, it should be stressed that the NaCl concentrations determined in cooked salmon after 9 days of storage in slurry ice were found to be lower than those described for fish material subjected to refrigeration in seawater (Smith, Hardt, McDonald, & Templeton, 1980).

Volatile amine formation

Increasing mean values of TVB-N were observed with longer storage periods (Table 2), but they were not significant; thus, an effect of the previous chilling time was not concluded. Comparison between raw fish before and after cooking did not lead to significant differences, although previous research carried out on albacore (*Thunnus alalunga*) showed a considerable TVB-N increase after cooking (Gallardo, Pérez-Martín, Franco, Aubourg, & Sotelo, 1990). The TVB-N content quantifies a wide range of basic volatile compounds (ammonia, methylamine, dimethylamine, trimethylamine, and so on), that should be produced as a result of microbiological activity during the chilling storage or arise from the thermal breakdown of endogenous compounds during cooking. Throughout the present experiment, the TVB-N index did not result in differences in quality deterioration.

Amine formation was also measured by the TMA-N content (Table 2). Its detection showed an important influence of the cooking process and the preliminary chilling time, so that both led to important increases in this metabolite. However, trimethylamine (TMA) formation in Coho salmon was low when compared to other fish species (sardine, albacore tuna) under similar conditions (Slabyj & True, 1978; Gallardo et al., 1990) and agrees to low levels found for trimethylamine oxide (TMAO) and TMA in salmon species (Barnett et al. 1991; Dondero, Cisternas, Carvajal, & Simpson, 2004). This low TMA formation may be of positive relevance in the sense that this metabolite is one of the main compounds involved in off-odour production in spoiled fish (Gallardo et al., 1990; Olafsdóttir et al., 1997). TMA formation in the actual cooked samples can be explained by means of two different pathways: i) As a result of TMAO bacterial catalysis breakdown during the chilled storage, and ii) TMA can be produced from TMAO by thermal breakdown during the cooking process. The great differences

found for the raw fish TMA-N values before and after cooking leads to the probable conclusion that thermal treatment has exerted a higher effect on the TMA formation than the previous chilled storage.

The pH value has been employed often as a complementary analysis to fish spoilage detection. In the present case, the pH value (Table 2) did not result in significant differences as a result of the previous chilled storage time, which agrees to the TVB-N content evolution observed and also agrees to the low TMA formation. As an explanation, it could be argued that a long chilled time was not encountered in the present study, since a lag phase round 12 days was previously observed for Coho salmon species under traditional icing (Aubourg et al., 2007). Furthermore the lower temperature of slurry ice of –1.5ºC has a dramatic effect on spoilage being fast slower at this temperature than at 0ºC (Yamada et al. 2002). In addition, no differences were observed between the pH value of raw fish before and after the cooking process.

Lipid hydrolysis analysis

A progressive increase in FFA occurred during storage (Table 2). Comparison of the initial raw fish before and after cooking showed that the thermal process did not lead to a variation in the FFA content of the fish muscle.

Different mechanisms involved in lipid hydrolysis can be discussed at the light of the different processing steps considered in this study. On the one hand, FFA formation during a relatively short chilled time occurs due to catalysis by endogenous enzymes, and only microbial effects would be significant after the end of the lag phase (Whittle et al., 1990; Olafsdóttir et al., 1997). Further, during a thermal treatment, breakdown of high-molecular weight (triglycerides and phospholipids, namely) lipids would be likely to occur and be the source of new FFA formation (Gallardo et al., 1989;

Yamamoto & Imose, 1989). The results shown in Table 2 indicate that it is probable that enzymatic formation of FFA is more important than effects of heating.

The formation of FFA itself does not lead to nutritional losses. However, accumulation of FFA has been related to some extent to lack of acceptability, because FFA are known to have detrimental effects on protein solubility and cause texture deterioration by interacting with proteins (Sikorwski & Kolakowska, 1994) and oxidise faster than higher-molecular-weight lipid classes (namely, triglycerides and phospholipids) by providing a greater accessibility (lower steric hindrance) to oxygen and other pro-oxidant molecules (Labuza, 1971).

Lipid oxidation analysis

The PV (Table 3) detection showed an important peroxide formation as a result of the cooking process, and also as a consequence of increasing the previous chilling time from 0 days to 5 days. Indeed, a remarkable peroxide content was obtained for cooked samples corresponding to a 5 days-chilled period. However, if the chilling time is further increased to 9 days, a peroxide formation drop is obtained in the resulting cooked salmon muscle. As an explanation, it could be argued that once the peroxide formation is initiated, values obtained are a balance between the rates of formation and rates of reaction (Aubourg, 1999).

The AV showed an important effect of the cooking process and also of the previous chilling time (Table 3). Thus, both process steps led to an increased formation of molecules susceptible to be measured by this index (alpha-unsaturated aldehydes, namely). Increases can be considered important, so that the AV has shown to be a useful tool for indicating both storage and cooking effects.

Secondary lipid oxidation compounds were also measured by the TBA-i (Table 3). Similar conclusions about its use in this context were drawn as for AV. Again, the secondary oxidation compound formation resulted in an interesting tool to assess the chemical changes produced as a result of the cooking process and as a result of a preliminary chilled storage. In this sense, previous research already accounts for carbonyl formation during cooking in sardine and tuna fishes (Yamamoto & Imose, 1989; Aubourg, Medina, & Pérez-Martín, 1995).

Interaction compound formation

Interaction compound formation was measured by means of the fluorescence and browning developments in the salmon muscle extracts, according to the Material and Methods section (Table 3). Both parameters showed a significant formation as a result of cooking and also with longer storage period. This increasing interaction compound formation agrees with the above mentioned results on secondary lipid oxidation compound (AV and TBA-i) and also with the peroxide content decrease observed for the cooked samples where a more advanced deterioration is expected to occur (9 days of preliminary chilling time). These results agree with previous work done on cooking of two tuna fish species (Aubourg et al., 1995).

The formation of interaction compounds (Pokorný, 1981; Aubourg, 1999) also called tertiary oxidation compounds, is the result of the interaction between lipid oxidation products (primary and secondary) and protein-like molecules present in fish muscle. The electrophilic character of most lipid oxidation compounds leads them to interact with food constituents possessing nucleophilic functions. Such interaction is highly favoured by a temperature increase. The interactions are very important secondary reactions of oxidised lipids, particularly in protein-rich foodstuffs such as

marine sources, which have high proportion of essential and reactive amino acids such as lysine and methionine. As a result, previous research has pointed out a partial loss of polyunsaturated fatty acids and essential amino acids, and some activity decrease of hydrolytic enzymes during cooking (Seet & Brown, 1983; García-Arias et al., 1994; Castrillón et al., 1996).

Textural properties

Firmness and cohesivity results are indicated in Figure 1. Firmness resulted in a differential effect of preliminary chilling storage so that an increasing value ($p<0.05$) was obtained with chilling time. On the other hand, cohesivity score showed to decrease with the storage time ($p<0.05$). As a result, it is concluded that a more breakable structure was obtained by enlarging the preliminary chilling storage.

The texture of the fish muscle depends on numerous intrinsic biological factors related to the density of the muscle fibres, as fat and collagen content of the fish (Sigurgisladóttir et al., 1999; Olafsdóttir et al., 2004). Previous research has shown that fish become less firm with longer chilling periods (Alasalvar, Taylor, Öksúz, Garthwaite, Alexis, & Grigorakis, 2001). However, heating converts the translucent, jelly-like cellular fish mass into an opaque and firmer material, where the connective tissue holding the cells together has been denatured and blocks of cells become readily separated from one another into flakes (Aitken & Connell, 1979). Changes of texture have been reported to be mostly due to crosslinking of peptide chains by reaction with lipid oxidation products, such as aldehydes (Pokorný, 1981; Sikorski & Kolakowska, 1994).

Sensory analysis

The rancid and putrid odour development was assessed in the cooked fish muscle. Results are shown in Figure 2. For both attributes, low scores obtained indicate a low rancid and putrid development, so that cooked fish can be considered as greatly accepted. No effect ($p>0.05$) of the previous chilling time could be assessed, according to the extended shelf life reported for salmon species under chilling conditions (Sveinsdóttir, Martinsdóttir, Hyldig, Jørgensen, & Kristbergsson, 2002).

Among the different chemical parameters related to quality loss studied in the present experiment, amine formation (total and TMA) and secondary lipid oxidation compounds (AV and TBA-i) are known to be the most closely related to the formation of putrid and oxidised flavours, respectively (White, 1994; Olafsdóttir et al., 1997). Actual sensory scores on putrid odour development greatly agreed to the results obtained for volatile amine formation (Table 2). However, sensory scores on rancid odour development do not agree to secondary lipid oxidation values (AV and TBA-i) obtained for the different kinds of cooked samples. It is likely that an extended study considering longer previous chilling times would have given more information on the correlation of lipid oxidation and sensory descriptors.

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FIGURE LEGENDS

Figure 1: Textural (firmness and cohesivity) change detection in cooked salmon that was preliminary chilled during 0, 5, and 9 days* (, , , respectively).

* Bars denote standard deviation of the mean (n=4).

Figure 2: Odour (rancid and putrid) detection in cooked salmon that was preliminary chilled during 0, 5, and 9 days* (, , , respectively).

* Bars denote standard deviation of the mean (n=4).

TABLE 1

Assessment of composition parameters* in raw and cooked salmon that was preliminary chilled

Salmon sample (raw / cooked)	Water content (g/ 100g muscle)	Lipid content (g/ 100g muscle)	NaCl content (g/ 100g muscle)
Raw salmon	75.66 b (1.27)	2.46 (1.03)	0.07 a (0.01)
Cooked salmon (0 days previous chilling)	70.37 a (2.11)	2.69 (0.41)	0.10 ab (0.04)
Cooked salmon (5 days previous chilling)	72.66 a (0.94)	2.42 (0.49)	0.13 b (0.01)
Cooked salmon (9 days previous chilling)	71.81 a (1.75)	2.31 (0.69)	0.21 c (0.01)

* Mean values of four independent determinations (n=4). Standard deviations are indicated in brackets. For each parameter, mean values followed by different letters (a, b, c) indicate significant ($p<0.05$) differences between the different kinds of samples.

TABLE 2

Assessment of spoilage parameters and lipid hydrolysis* in raw and cooked salmon that was preliminary chilled**

Salmon sample (raw / cooked)	TVB-N (mg/ 100g muscle)	TMA-N (mg/ 100g muscle)	pH	FFA (g/ 100g lipids)
Raw salmon	23.28 (0.67)	0.05 a (0.01)	6.61 (0.04)	0.16 a (0.07)
Cooked salmon (0 days previous chilling)	23.21 (0.69)	0.29 b (0.08)	6.61 (0.04)	0.13 a (0.03)
Cooked salmon (5 days previous chilling)	24.87 (0.90)	0.37 bc (0.05)	6.62 (0.02)	0.83 b (0.30)
Cooked salmon (9 days previous chilling)	25.80 (2.75)	0.47 c (0.06)	6.66 (0.02)	2.32 c (0.94)

* Mean values of four independent determinations (n=4). Standard deviations are indicated in brackets. For each parameter, mean values followed by different letters (a, b, c) indicate significant ($p<0.05$) differences between the different kinds of samples.

** Abbreviations employed: TVB-N (total volatile base-nitrogen), TMA-N (trimethylamine-nitrogen), and FFA (free fatty acids).

TABLE 3

Assessment of lipid oxidation and interaction compound formation* in raw and cooked salmon that was preliminary chilled**

Salmon sample (raw / cooked)	PV	AV	TBA-i	FR	Browning
Raw salmon	1.38 a (0.58)	1.15 a (0.25)	0.02 a (0.01)	0.14 a (0.05)	0.87 a (0.11)
Cooked salmon (0 days previous chilling)	4.15 b (0.72)	5.57 b (2.16)	0.52 b (0.10)	0.54 b (0.10)	1.32 b (0.11)
Cooked salmon (5 days previous chilling)	13.80 c (2.06)	25.76 c (1.65)	0.67 b (0.18)	0.79 bc (0.19)	2.04 bc (0.44)
Cooked salmon (9 days previous chilling)	5.52 b (0.56)	53.03 d (0.48)	1.11 c (0.16)	0.93 c (0.11)	2.43 c (0.19)

* Mean values of four independent determinations (n=4). Standard deviations are indicated in brackets. For each index, mean values followed by different letters (a, b, c, d) indicate significant ($p<0.05$) differences between the different kinds of samples.

** Abbreviations employed: PV (peroxide value), AV (anisidine value), TBA-i (thiobarbiruric acid index), and FR (fluorescence ratio). Units employed: meq active oxygen/ kg lipids (PV) and mg malondialdehyde/ kg muscle (TBA-i).

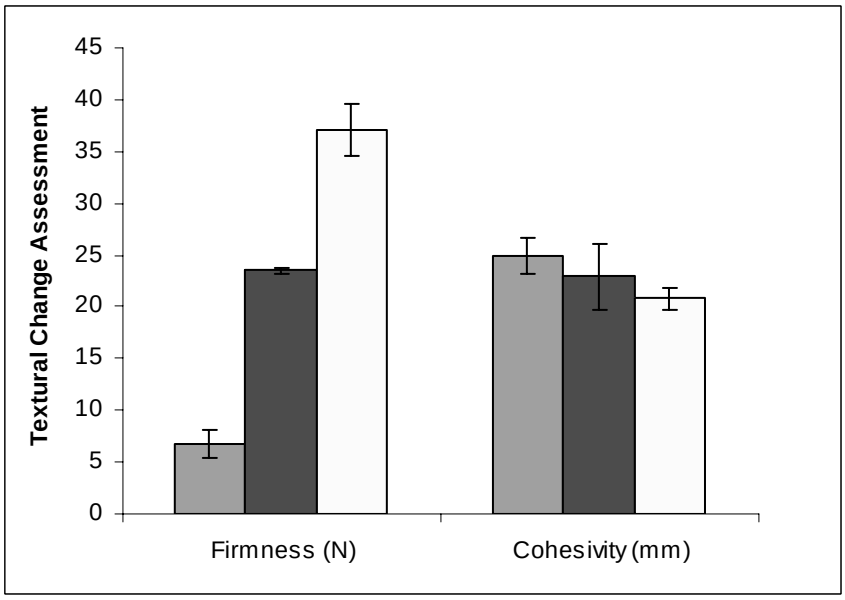

Figure 1

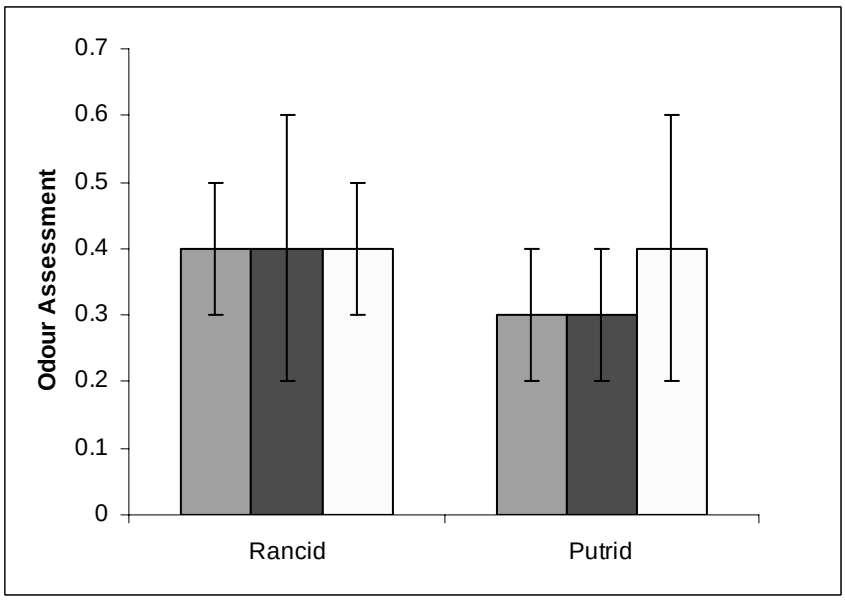

Figure 2